Chapter 5
EROSION, TRANSPORT, AND DEPOSITION OF COHESIVE SEDIMENTS

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Chapter III-5
Erosion, Transport, and Deposition of Cohesive Sediments

III-5-1. Introduction

a. Cohesive sediments are those in which the attractive forces, predominantly electrochemical, between sediment grains are stronger than the force of gravity drawing each to the bed. Individual grains are small to minimize mass and gravitational attraction, and are generally taken to be in the silt (<70 μ) to clay (<4 μ) range. The strength of the cohesive bond is a function of the grain mineralogy and water chemistry, particularly salinity. Thus, a coarse silt behaves like noncohesive fine sand in fresh water, but is cohesive in an ocean environment. Similarly, a fine sand exhibits cohesion in salt water. In other words, it is easier to define cohesive sediment by behavior than by size.

b. Grain size and shape nevertheless play a significant role in the lack of permeability of cohesive sediment. As grain size decreases, so does the size of the interstitial pore spaces while drainage path length increases. The small pores result in greater resistance to flow, exacerbating the effects of the long drainage path. Clay minerals tend to form flake-shaped platelets, rather than spherical particles. These platelets deposit with the smallest dimension vertical, further reducing pores and increasing vertical drainage paths. For this reason, clay is often used as an impermeable layer in hydraulic earthworks such as dikes and channels.

c. In coastal engineering terms, the principal indicator of cohesive sediment behavior is a critical shear for erosion of bed sediment τ_e, which is significantly greater than the critical shear for deposition τ_s. In other words, once the sediment has been deposited on the bed, the cohesive bond with other bed particles makes it more difficult to remove than particle mass alone would suggest.

d. The processes and states of coastal cohesive sediment listed below are shown schematically in Figure III-5-1 and Table III-5-1.

(1) Consolidated. Stiff or hard cohesive sediment that has had centuries to drain, probably compressed beneath glaciers or other overburden.

(2) Suspension. Individual grains or flocs dispersed in the water column and transported with the water.

(3) Fluid Mud. A static or moving intermediate state between suspension and deposition, analogous to bed-load transport of noncohesive sand, that can move in the direction of flow supported by the bed. Fluid mud is the result of excess pore pressure, built up by hindered settling or wave action. Water cannot escape from the sediment deposit, and builds up the excess interstitial pore pressure necessary to support the weight of sediment above it. The whole mass of sediment and trapped water behaves like a uniform dense viscous fluid, flowing downhill or in the direction of the water flow. Fluid mud layers can often be seen on echo soundings as a false bottom in depressions in the seabed.

(4) Mud. Unconsolidated cohesive sediment that has been recently deposited. ‘Recently’ may be a matter of a few hours to several years.

e. Processes and states in Figure III-5-1 may be skipped. For example: most coastal mud, even fluid mud, is eroded before it has undergone sufficient consolidation to be defined as ‘consolidated’; many cohesive sediments do not form fluid mud, but deposit directly as stationary mud. Differences between mud and consolidated sediments occur during erosion. Transport, deposition, and consolidation are the same for both mud and consolidated cohesive sediments.

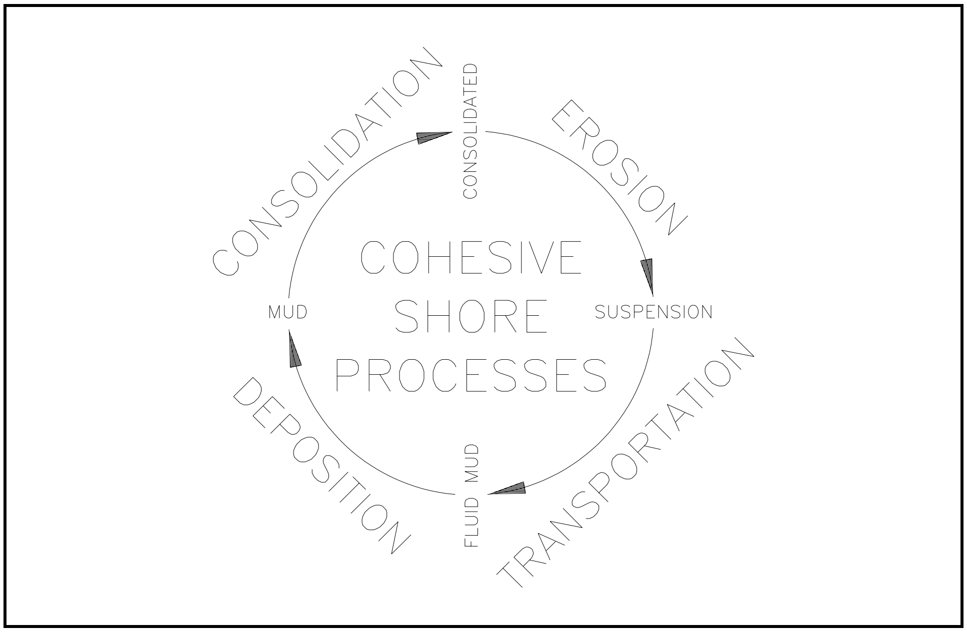

Figure III-5-1. Outline of cohesive shore processes — Any process or state may be bypassed, for example, fluid mud may be eroded without passing through (further) deposition and consolidation

Table III-5-1
Cohesive Sediment Density

	Typical Saturated Bulk Density	
Soil Description	**kg/m^3**	**lb/ft^3**
Suspension	1,020	64
Fluid Mud	1,100	70
Freshly Deposited Mud	1,300	80
Very Soft Consolidated	1,500	90
Soft Consolidated	1,600	100
Medium Consolidated	1,800	110
Stiff Consolidated	1,900	120
Very Stiff Consolidated	2,100	130
Hard Consolidated	2,200	140

III-5-2. Consolidated and Unconsolidated Shores

a. Consolidated shore.

(1) A shore is defined as consolidated cohesive when the erosion process is directly related to the irreversible removal of a cohesive sediment substratum (such as glacial deposits, ancient lagoon peats, tidal flat muds, valley and bay fill muds, lacustrine clays, flood deltas consisting of fine sediments, soft rock or other consolidated or over-consolidated deposits). Even when sand beaches are present, under the sand beach there lies an erodible surface that plays the most important role in determining how these shores erode, and ultimately, how they evolve in the long term. This differs fundamentally from sandy shores where erosion (or deposition) is directly related to the net loss (or gain) of noncohesive sediment from a given surface area.

Erosion on a sandy shore is a potentially reversible process (i.e., due to natural processes), while erosion on a consolidated cohesive shore is irreversible.

(2) Consolidated shores consist of consolidated or partially consolidated cohesive sediments which are usually covered by a thin veneer of sand and gravel, sometimes forming a beach at the shore (Part III-5-3 describes the techniques available for determining the properties of cohesive sediment). In essence, these shores are defined by an insufficient supply of littoral sand and gravel (i.e., noncohesive sediments). Consolidated shorelines may be associated with an eroding bluff or cliff face, or they may consist of a transgressive barrier beach perched over older sediments. The sand veneer often disguises the underlying cohesive substratum, and therefore, at many locations consolidated shores are incorrectly assumed to behave as sandy shores. The veneer thickness is usually in the range of a few centimeters to 2 or 3 m.

(3) Consolidated cohesive shores compose a large part of the Great Lakes, Arctic, Atlantic, Pacific, and U.S. Gulf coasts, a large part of the North Sea coast of England, and sections of the Baltic and Black Seas. Examples along the U.S. Atlantic coast include many of the barrier islands that are perched over older consolidated sediment; Riggs, Cleary, and Snyder (1995) estimate that 50 percent of the North Carolina coast is underlain by older estuarine peats and clays. Other examples along the U.S. east coast include the shores of Chesapeake and Delaware Bays. In many instances, the erosion of the shores associated with the Mississippi Delta and the transgressive barrier islands along the Texas coast is the result of cohesive processes. Cliff erosion along the South California coast and along large parts of the Beaufort Sea coast of Alaska are related to an insufficient supply of littoral sand, the hallmark of consolidated cohesive shores. Many other examples throughout the world, including erodible rocky coasts, are cited by Sunamura (1992). As awareness of the importance of the distinction of this shore type grows, and as sub-bottom investigations become more prevalent, more examples are identified. As Riggs, Cleary, and Snyder (1995) note, in many cases the shore is not just a ‘thick pile of sand.’

(4) Consolidated cohesive shores are often difficult to identify owing to the presence of a sand beach at the shore. The existence of an eroding bluff or cliff at the shore, featuring consolidated or cohesive sediment of some form, is a sure sign of a consolidated shore. However, in many cases, cohesive shores do not feature eroding bluffs. Examples include many of the barriers along the Atlantic and U.S. Gulf coasts.

(5) There are at least six ways of visually identifying the presence of underlying consolidated cohesive sediment, which would distinguish a consolidated cohesive shore from a sandy shore. A series of photos of a transgressive shoreline along the east coast of Ghana in West Africa provide examples of the different types of evidence which may indicate the presence of cohesive sediment under a sand beach. Long-term recession rates along this 7-km section of the Ghanaian coast are in the range of 2 to 8 m/year. The six distinguishing features are:

(a) The most straightforward evidence is the presence of exposed cohesive sediment on the beach. Figure III-5-2 shows a large expanse of peat exposed on the beach in Ghana. Such exposures may be infrequent and result from severe erosion events (where the overlying sand is stripped and carried offshore) or may appear between large alongshore sand waves.

(b) Pieces of clay or peat on the beach. Figure III-5-3 shows some angular clay blocks that have been removed from the seabed and transported towards the shore, along with some pieces of rubble from old buildings that have been destroyed by erosion. In many locations, clay balls can be found along the shoreline. The more rounded clay pieces probably result from transport over a greater distance, i.e., the exposed cohesive sediment may not be located in the immediate vicinity of where the clay balls are found.

Figure III-5-2. Peat exposed on a beach along the Keta shoreline in Ghana, West Africa, May 1996

Figure III-5-3. Pieces of eroded clay (and some rubble) scattered on a beach along the Keta shoreline in Ghana, West Africa, September 1996